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Volume 4, Number 3, July 1983

Indoor Air Quality in Office Buildings

An Evaluation of the Vertical Elutriator for Cotton Dust Sampling

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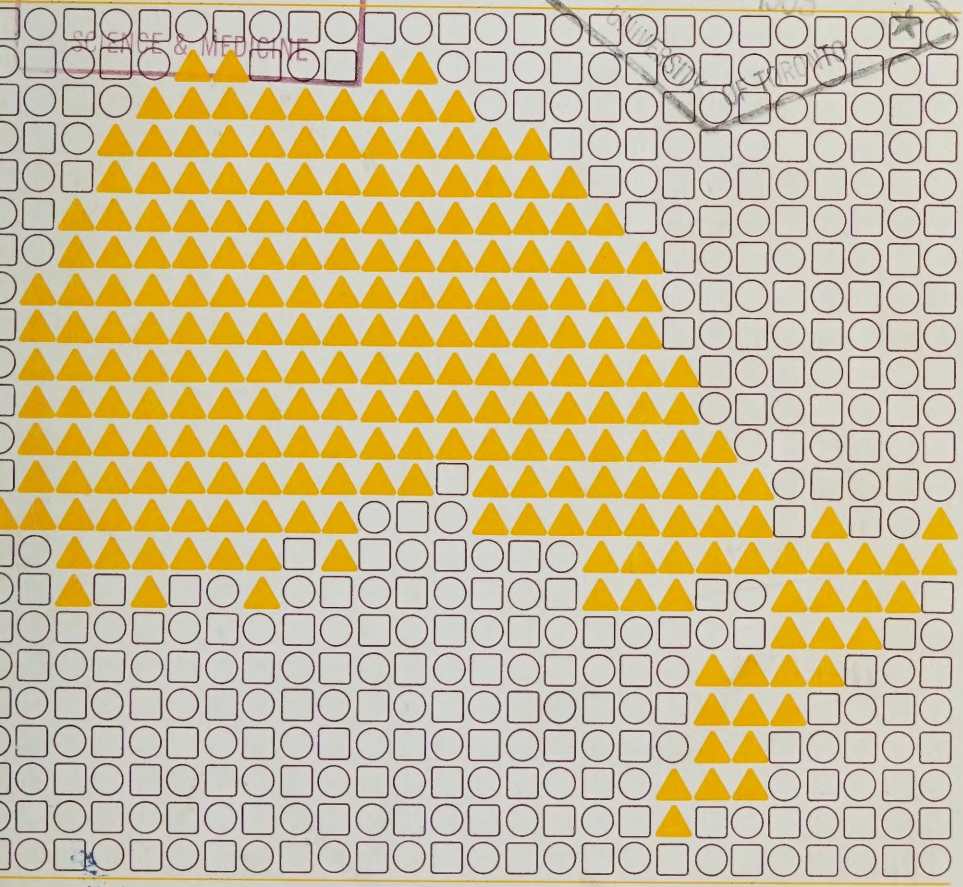

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Occupational Health in Ontario

Volume 4, Number 3, July 1983

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Correspondence

To The Editor

Further to my article on Lead in Indoor Pistol Ranges* I submit the following:

After high airborne lead levels were demonstrated in Pistol Range F in July of 1981, modifications were made under the supervision of Mr. L. Tremblay of Tremblay Engineering Ltd. (Cornwall) in consultation with Mr. B. Stimson of the National Research Council in Ottawa. The modifications were designed to increase the air velocity at the firing line and to minimize turbulence in the 'wind shadow' of the shooter.

The air velocity at the firing line was increased by increasing the total ventilatory capacity of the range and by decreasing the cross-section of the area to be ventilated. The latter was accomplished by the construction of a partial wall across the range at the front of the shooting stalls. This wall consisted of a barrier dropped from the ceiling and the installation of openable half-doors in the lower portion of the shooting stalls. Such an arrangement has the flexibility to allow standard shooting in the standing position and 'combat shooting', in which the prone and sitting positions are used.

The device used to minimize turbulence in the 'wind shadow' of the shooter consists of a small 'hair dryer' type fan blowing air into a perforated tube. One such device has been placed vertically on either side of the back of each shooting stall. The tube is positioned so that the perforations direct air forward from behind the shooter at an angle of about 45° to a convergence point at about the shooter's wrist.

The following Table summarizes the test results before and after the range modifications were made. It is noted that the shooting protocol and testing procedures were identical for both tests.

	Mean Air Lead (mg/m^3)	Estimated Air Velocity (ft/min)
July 1981	3·45	7·4
January 1983	0·16	90·3

These test results demonstrate that a marked decrease in air lead levels has been achieved by the modifications described above. Previous personal experience suggests that increased air flows alone cannot account for this remarkable improvement. The simple devices used to minimize turbulence in the 'wind shadow' would appear to deserve further evaluation and application.

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*Waddell W.R. Lead in Indoor Pistol Ranges. Occupational Health in Ontario 1982; 3: 198-205

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Indoor Air Quality in Office Buildings

Summary

The environmental factors affecting indoor air quality and ventilation standards are discussed. Air quality in offices may be considered under two categories: air contaminant and comfort. Carbon dioxide is considered to be a more sensitive indicator than oxygen deficiency for the quantity of fresh air required, while comfort parameters also include temperature, humidity and air movement. It is concluded that health problems are not a major concern: however, ventilation problems give rise to comfort concerns, and these are the predominant complaints of occupants.

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In recent years it has been recognized as important for the health and comfort of the occupants to control the quality of air in office buildings. Published reports [1, 2, 3, 4] have indentified this potential health problem. While all the incidents of inferior air quality related to building type, size and location are seldom reported, the Occupational Health Branch has investigated many health and comfort complaints in office buildings in the province of Ontario. In the majority of cases employees complained of 'stuffiness, drowsiness, tiredness, eye irritation and nausea'. The alleged cause of these health problems was stated to be 'stale air' or 'lack of oxygen' in the work environment.

Most of the symptoms cited were invariably reported in airtight, multistorey buildings equipped with central heating, ventilation and air-conditioning systems (HVAC). In some cases a definitive cause of the symptoms could not be found; hence, investigators dealing with these 'mysterious illnesses' started using the term 'tight building syndrome'[4] to describe the alleged symptoms. Obviously, reduced ventilation rates, altered air distribution and environmental conditions in buildings have a direct bearing upon indoor air quality.

The purpose of this paper is to present a review of indoor air quality criteria and ventilation standards, and to suggest evaluation guidelines for air quality and comfort parameters.

Environmental Factors Affecting Indoor Air Quality

Indoor air quality is an extremely complex function of a number of variables. Some of the factors[5] that can affect indoor air quality are:
building ventilation and air-conditioning systems;
indoor sources and generation of contaminants;
outdoor ambient air pollution;
weather conditions;
energy conservation measures.

(i) Building Ventilation and Air-Conditioning Systems

Building ventilation is the single most important factor that has a direct effect on indoor air quality at any geographical location. In order to adequately determine the impact of reduced ventilation on indoor air quality,[6] buildings have been broadly divided into two categories: conventional and energy efficient buildings.

Conventional Buildings

In conventional buildings ventilation is obtained by mechanical means or by opening windows and doors if weather conditions are favourable, thereby allowing indoor contaminants to be diluted. The indoor concentrations in such buildings will eventually approach those persisting in the outdoor atmosphere.

Energy Efficient Buildings

In energy efficient, 'airtight' (window sealed and air-conditioned) buildings attempts are made to reduce air infiltration and exfiltration by tightening the building envelope. Indoor air is recirculated to conserve heat in the winter and to reduce cooling requirements in the summer. Quantities of outside air are introduced to the recirculation cycle to provide contaminant dilution, and approximately equal quantities of air are exhausted from the cycle to provide a system balance and clearance of contaminants. While the quality of outside air has a bearing on the indoor air quality in these buildings, it is mainly a function of the accumulation of indoor-generated air contaminants. In excessive concentrations these contaminants may impair the health of the occupants, but they are generally present only at concentrations that affect their comfort.

An air-conditioning system that includes filtration, air washing and humidification is likely to result in lower concentrations of particulates and sulphur dioxide (SO_2) indoors than are present outdoors.

(ii) Indoor Sources and Generation of Contaminants

Typical air contaminants in buildings include a wide spectrum of gaseous, particulate and even radioactive contaminants. Some of the major indoor air pollutants

and their potential sources[7] in buildings are listed below:

Human Activities
Metabolic—CO_2 (carbon dioxide), NH_3 (ammonia), organics, odours.
Tobacco smoking—CO (carbon monoxide), NO_2 (nitrogen dioxide), aldehydes, particulates.

Building Contents
Furnishings—Organics, odours.
Photo copiers—Organics, O_3 (ozone).

Building Materials
Fire retardants—Asbestos fibres, mineral wool.
Particle board—Formaldehyde.
Concrete—Radon.

Air contaminants generated at any point indoors tend to diffuse throughout an enclosed space. A number of energy conservation measures can significantly change the dilution capacity of the ventilation system and may alter the quality of air in a building. Floor plan alterations are the most prevalent causes of ventilation problems since these alterations generally interfere with the original design of the air flow. Hence, 'pockets' of air contaminants may occur if the design air flow has been altered without consideration of the contaminant source.

(iii) Outdoor Ambient Air Pollution

The air surrounding a building constantly tends to infiltrate an enclosed space depending on whether the building has natural or controlled ventilation. The degree of infiltration is influenced by the type of pollutant present. Due to their aerodynamic behaviour, particles are partly removed in the infiltration process, whereas an unreactive gas like CO easily penetrates. In addition, the proximity of a building to any stationary or mobile contaminant sources may have a significant influence on the quality of indoor air. Recirculation of combustion products and location of the building air intake can strongly influence the indoor air quality. Outdoor sources of indoor pollution usually contain the following contaminants: SO_2, oxides of nitrogen (NO_X), O_3, CO, particulates, etc.

(iv) Weather Conditions

Indoor air quality is sometimes directly related to temperature inversions in the outdoor environment. Temperature inversions are known to elevate the outdoor pollutant concentrations at ground level. Consequently, outdoor air entering a conventional building during a temperature inversion condition will influence the quality of indoor air. Similarly, indoor-outdoor temperature gradients can also affect indoor air quality in a conventional building due to a 'stack effect' in cold weather, thereby causing outdoor air to enter at lower levels.

Wind can produce pressure differences between the inside and outside, which facilitates the tendency for the external pollutants to infiltrate or for the internal pollutants to be diluted more quickly. Again, this will modify indoor air quality in a conventional building and, to a lesser extent, in a 'weatherless' airtight air-conditioning building.

(v) Energy Conservation Measures

The current trend in new office building design and construction favours the energy efficient type of building. Most of the new high rise office buildings are built to be energy efficient. Even some of the conventional buildings are being converted into energy efficient buildings.

Traditionally, it has been presumed that if the outdoor ambient air is free of contaminants, indoor air, likewise, will be free of contaminants. This may be true for a conventional building, wherein ventilation is obtained strictly by opening windows and doors, provided weather conditions are favourable. However, for an energy efficient building the presumption may not be valid. To some extent, the maximum recirculation of conditioned air in such a building will reduce the impact of outdoor air quality, but it will maximize the influence of indoor generated pollutants.

The 'tight building' depends on the controlled addition of fresh, outside air to the recirculated air to provide a supply of air to satisfy the respiratory requirements of the occupants as well as dilution of any airborne contaminants. The quantity of outside air added to the recirculated air is often adjusted to effect economies in the energy requirements for either heating in the winter months or cooling in the summer months. Unfortunately, the energy conservation viewpoint often

overrides the occupant health and comfort viewpoint with resultant complaints of 'stale air' or a 'lack of oxygen'.

The severity of health problems allegedly caused by inferior air quality in energy efficient buildings is illustrated by the case of a 'concrete cast-in-place', eight storey energy efficient office building, built in 1979, in San Francisco.[8] All ventilation for the building was through central HVAC equipment. Occupants of this building complained that 'they get sick just by being in the building.' Hearings on such buildings that made occupants sick were held throughout California by Pleasanton's Democrat Assemblyman, Floyd Mori. These hearings were organized to change building energy efficient standards and the results of these hearings should be available in due course.

Ventilation Standards and Indoor Air Quality

There has been continual disagreement among researchers involved with ventilation and air quality about the ventilation requirements of an occupied space. Several building codes now refer to the American Society of Heating, Refrigeration and Air-conditioning Engineers' (ASHRAE) handbooks for design purposes, but the historical development of the standards is interesting.

An account of changing concepts in ventilation requirements is given by Klauss *et al.*[9] The earliest theory pertaining to ventilation requirements probably evolved in the 17th or 18th century. It was believed that accumulation of bad breath and perspiration from human beings crowded in a confined space were responsible for producing plague or fever, although subsequent medical theories, based on micro-organisms, disproved this belief. In addition, depletion of oxygen by the occupants of a confined space was thought to be a consequence of improper ventilation. This theory was proved wrong by Lavoisier in about 1877. Lavoisier postulated that 'instead of oxygen being depleted, it was the increase in CO_2 content that was responsible for the unhealthful atmosphere of confined spaces.' He maintained that the increased CO_2 content of air interfered with the body's ability to absorb oxygen. Although this theory is also incorrect, it predominated in physiological circles for nearly 100 years. During this period a number of researchers believed the organic substances in the exhaled air to be the actual contaminants that caused 'vitiation' of the air.

Furthermore, a number of them suggested that CO_2 could be used as a measure of the amount of these organic contaminants present in the air.

In 1883 Hermans proposed a new theory of ventilation requirements, which proved to be a turning point in ventilation study. He suggested that it was actually interference with the heat loss process that produced adverse physiological effects on the human body confined in poorly ventilated quarters. Researchers in the following years verified this theory experimentally by confining a subject in a small chamber with two separate air supply systems. By varying the air supply system's parameters, such as odour, temperature, moisture and carbon dioxide level, it was shown that excessive temperature was the 'contaminant' that caused the body to react adversely. At that time primarily natural ventilation was used for thermal and air quality control. With increasing population in urban centres, land became more expensive and building design changed to accommodate more people under the same roof. This led to the development of multistorey buildings, and natural ventilation was no longer adequate to control the indoor environment in such buildings. By the end of the 19th century ventilation codes and standards were adopted in the Unied States.[10] Historical developments in ventilation standards are shown in Figure 1.

Figure 1 **Developments in Ventilation requirements**

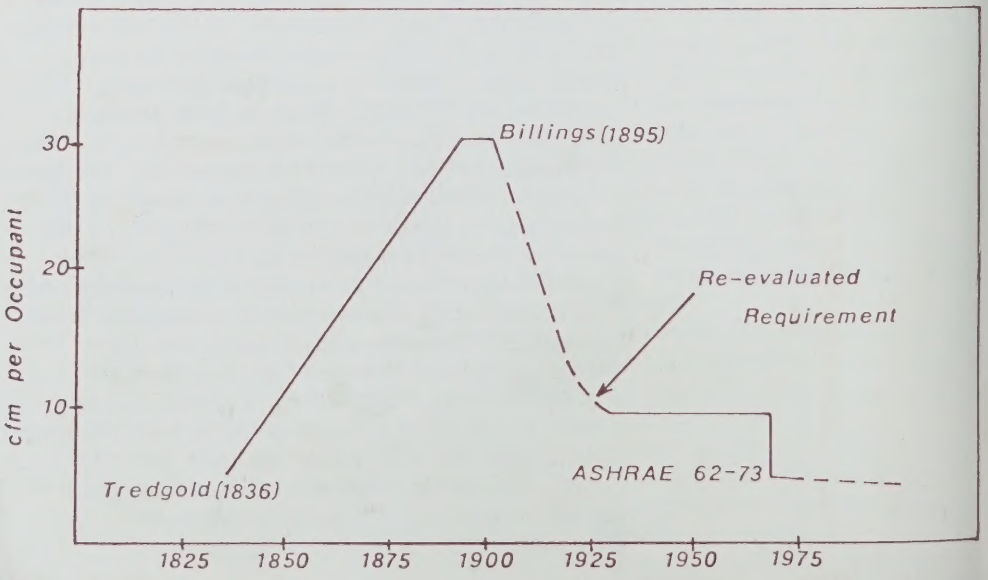

Figure 1 illustrates ventilation rates increased from four cubic feet per minute (cfm) in 1836 to a maximum of 30 cfm per occupant in 1895. A significant change in ventilation requirements resulted from the experimental work of Yaglou *et al*[11] reported in the 1930s. Their studies recognized the importance of controlling indoor air quality as well as ventilation rates in the cfm per occupant required to provide an 'odour-free' environment. These ventilation rates were based on the assumption that outdoor 'fresh air' was odour-free. For about 35 years the Yaglou studies served as the primary reference in ventilation codes and standards.

In the late 1960s ASHRAE undertook an extensive program to develop a ventilation standard. Finally, in 1973 the ASHRAE Standard 62-73 for Natural and Mechanical Ventilation was published, which specified,[12] for the first time in the history of ventilation standards, a quantitative definition of 'acceptable outdoor air'. In 1977 this standard was adopted by the American National Standard Institute (ANSI), under the designation ANSI Standard B194.1.

ASHRAE Standard 62-73

This Standard specified both 'minimum' and 'recommended' ventilation rates for spaces intended for human occupancy. However, it does not specify the air quantities needed for the control of excessive temperature and humidity or the exhaust quantities required for source control of pollution. The specified ventilation rates are based on the current state of knowledge and acceptable practice related to air filtration, odour control and environmental physiology. In addition to specifying air quality parameters for the outdoor ventilation air, the Standard also states the air containing any contaminant in a concentration greater than one-tenth of the latest Threshold Limit Value (TLV) shall be considered unacceptable for ventilation purposes.

The requirements for ventilation rates given in the Standard are for 100 per cent outdoor air when the outdoor air meets the air quality specifications indicated therein. The Code also recommends that the outdoor air requirements may be reduced to 33 per cent of the required ventilation air quantity if adequate temperature control is provided in addition to filtering equipment. This reduced air requirement is not recommended for areas where recirculation is prohibited by other codes or

standards. In addition, if highly efficient odour and gas removal equipment is used to meet the air quality specifications set out in the Standard, the outdoor air requirement may be further reduced to 15 per cent of the specified ventilation air quantity. Concerning the ultimate minimum requirement for recirculation, the Standard states that 'In no case shall the outdoor air quantity be less than 5 cfm per person.'

ASHRAE Standard 90-75

To improve the conservation of energy in new buildings, ASHRAE undertook another intensive program and developed a new ventilation standard, ASHRAE Standard 90-75,[13] which was published in 1975.

ASHRAE 90-75 did not change the ventilation requirements of Standard 62-73, but incorporated them into the new Standard. In formulating ASHRAE 90-75, the standard committee unfortunately chose to conform to the 'minimum' ventilation air quantity in order to conserve energy by limiting the number of air exchanges. In other words, the Standard effectively deletes the 'recommended' column set out in Standard 62-73.

In a report[14] on the impact assessment of ASHRAE Standard 90-75, it has been stated that the use of 'minimum' ventilation rates resulted in an increase of approximately 67 per cent in the pollution level in an office building. In this study cigarette smoke particulate concentrations were monitored to measure the pollution levels. The report finally suggests that smoking spaces in public buildings be ventilated at ASHRAE 62-73 'recommended' rates rather than at the 'minimum rates' chosen in Standard 90-75. An interesting compromise, but an obvious implementation impossibility for the building ventilation staff. This double standard does not consider ventilation for areas with duplicating machines, computer and video display terminals, blueprint machines and various other sources of indoor-generated contaminants.

ASHRAE Standard 62-1981

In an effort to resolve some of the problems associated with Standard 90-75, in January 1981 ASHRAE adopted Standard 62-1981. The important features[15] of this Standard are:

specifies acceptable outdoor air quality;

specifies the treatment of ventilation air;
describes methods for variable ventilation rates;
alternative performance method specified for both the objective and subjective criteria for indoor air quality.

In general, compared to the previous standards (ASHRAE 62-73 and 90-75), 62-1981 is more specific regarding the requirements of recirculation air flow rates and air cleaner efficiencies.

Indoor Air Quality Criteria

In broad terms, indoor air quality in office buildings may be considered under two categories: (a) air contaminants and (b) comfort. A survey of indoor air quality criteria, including their numerical values, has been described in a report[16] published by the U.S. Environmental Protection Agency (EPA). The recommended criteria for comfort parameters may be found in the latest edition of the ASHRAE Handbook of Fundamentals.

In the EPA report, indoor quality standards for air contaminants have been classified into three categories: (a) maximum allowable air quality standards (b) design level standards and (c) emission standards.

Maximum allowable air quality standards specify a numerical value for a contaminant's concentration in air. Design-level standards specify a numerical value for the volume of air required to be used for ventilation. Emission standards specify a numerical limiting value for the amount of contaminant that may be released from a source.

In Ontario there are no design level or emission standards for office building air quality. In accordance with the provisions of section 1(13) of the *Ontario Occupational Health and Safety Act,* an office building is classified as an 'industrial establishment'. Hence, occupational guidelines and Threshold Limit Values (TLVs) adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) combined with specific Ontario guidelines are used to evaluate contaminant levels in office buildings.

In principle, a number of constituents of indoor air, such as odour, CO_2, O_2, water vapour, etc., which are sensitive to building occupancy, could be chosen as criteria of indoor air quality. Turiel *et al*[17] evaluated the practical problems associated with each of these parameters and demonstrated the point that CO_2 is a better indoor quality detector than O_2.

'Lack of oxygen' is a common air quality complaint of occupants in buildings. Using the ASHRAE recommended minimum air volume rate/person of outside air per occupant to limit the CO_2 concentration to less than 5,000 ppm, Turiel has clearly shown that 'lack of oxygen' is incorrect terminology to describe inferior air quality.

At the ASHRAE[12] recommended minimum ventilation rate of 8·5 m^3/h (or 5 cfm) per occupant and at equilibrium the O_2 concentration would decrease from 20·6 per cent to 20·1 per cent, which is well above the level at which adverse physiological effects occur. Oxygen concentrations below the 16·5 per cent level are known to cause dizziness and headache.

Turiel further estimated that even at a reduced ventilation rate of 4·7 m^3/h (or about 3 cfm) per occupant, the CO_2 concentration will reach 5,000 ppm, but the O_2 concentration will drop to only 19·8 per cent which, again, is well above the 16·5 per cent safe level. The reduction in O_2 concentration does not call for any action, but at 5,000 ppm CO_2 concentration it would be necessary to decrease the CO_2 concentration by the addition of fresh outside air. It is unlikely that the level of 16·5 per cent O_2 would occur in office buildings under normal conditions. However, if changes in O_2 are the result of elevated CO_2 levels, it is apparent that minor changes in the O_2 level could result in significant levels of CO_2, which would physiologically affect the occupants. It is concluded, therefore, that CO_2 is a more sensitive indicator of occupancy than O_2.

It is unlikely that CO_2 levels will reach the 5,000 ppm TLV level; however, elevated CO_2 levels indicate insufficient addition of fresh air to the HVAC system. Hence, CO_2 can be used as an indicator of indoor air quality, and experience has shown that CO_2 levels above 1,000 ppm are likely to be associated with occupant discomfort. CO_2 levels in the 600 to 1,000 ppm range may result in an increased incidence of occupant discomfort, whereas levels below 600 ppm are generally associated with an adequate addition of fresh air to the HVAC system.

Evaluation of Indoor Air Quality Parameters

Details of air sampling equipment and procedures are well documented elsewhere.[18,19,20] In recent years a custom-built mobile laboratory to study ventilation and air quality in energy efficient buildings has been designed and fabricated at the Lawrence Berkeley Laboratory,

University of California.[21] Sampling lines from the laboratory lead to several different sites inside a building, and by sequential sampling the air quality is monitored in several rooms.

Obviously, a fully equipped mobile laboratory is not readily available for all indoor air quality assessments, so the investigator must, of necessity, limit the investigation to assessment of parameters that are related to the complaint(s).

a) Air Contaminant Parameters

For the purpose of air quality evaluations the most common and readily measurable contaminants are CO, CO_2 and particulate matter. Measurement methodologies for these are well documented in the literature cited previously.

In the absence of sufficient fresh outdoor air, cigarette smoke and human respiration increase the CO_2 content of indoor air. Several direct reading devices are available for the measurement of CO_2 in occupied spaces. The most common instruments are based on the nondispersive infrared principle. Inexpensive direct reading colorimetric detector tubes[22] can also be used for spot checking the CO_2 concentration down to the 320 ppm level, which is the CO_2 level of fresh air.

In recent years mechanical ventilation systems, based on CO_2 as an indicator of air quality, have been installed in office buildings.[23],[24] The study conducted by Nakahara *et al*[23] showed that 5 m^3/h per occupant was the lowest fresh air ventilation rate to maintain the indoor CO_2 concentration below the Japanese standards of 1,000 ppm.

b) Thermal Comfort Parameters

Temperature, humidity and air movement are the thermal comfort parameters of interest in office buildings. In the absence of radiative heat load, effective temperatures have also been used as valid criteria to specify permissible thermal conditions.[25] In dealing with the complaints of 'stuffiness', 'stale air', 'lack of oxygen', etc., the following measurements have been found to be useful in evaluating the general thermal comfort conditions in offices:
dry bulb temperature;
wet bulb temperature;
humidity;

air movement;
CO_2 content of the air.

The most commonly used comfort chart is the one developed by ASHRAE, which uses wet and dry bulb air temperatures and humidity as comfort parameters, and which has been described in a NIOSH publication.[27] The comfort zone is that combination of environmental conditions that is thermally neutral to the human body. The comfortable temperature range for office workers has been specified as '68 to 74°F during winter months and 75 to 82°F in summer with moderate humidities.' For air movement measurements, the instruments of choice are those that depend upon the cooling of a heated element, such as a thermoanemometer or the Kata thermometer. The Kata thermometer provides a better estimate of air movement than a thermoanemometer, whereas a velocity meter or smoke tube are required to determine directional flow. Carbon dioxide measurements have been discussed in the section on air contaminant parameters.

Thermal comfort criteria, as published by ASHRAE, are used in conjunction with the contaminant criteria and ventilation requirements to complete the evaluation of indoor air quality of office buildings.

Indoor Air Quality Control

The four basic objectives of air quality control through ventilation are:

a) provision of sufficient oxygen for normal respiration;
b) dilution of contaminants within occupied spaces;
c) pressurization of occupied spaces to control infiltration or exfiltration;
d) removal of thermal loads generated within occupied spaces.

The strategies of indoor air quality control have been systematically outlined by Woods *et al.*[28] Control of indoor air quality is based on three sets of criteria: environmental, economic and energy consumption. Basically, the three common methods of indoor air quality control are:

Source Control—to minimize the generation of indoor contaminants by isolation or local exhaust.

Dilution Control—to dilute the contaminants by natural or mechanical ventilation.

Removal Control—to reduce indoor contaminant concentrations by means of air cleaning devices.

Despite the availability of modern sophisticated HVAC systems, the role of windows in the heating, cooling and ventilating of buildings has been reviewed at a recent ASHRAE meeting.[29] Recognizing the indoor air quality problems and associated health symptoms in office buildings, ASHRAE advises the opening of windows when conditions are favourable. One must assume this reference relates to conventional buildings and, therefore, does not consider the energy efficient building.

Conclusions

Depending on the type of architectural construction, indoor air quality in an office building is strongly influenced by a number of factors, such as building ventilation, indoor and outdoor sources of contaminants, energy conservation measures, floor plan modifications and atmospheric conditions.

Due to an increased awareness of the effects of workplace environmental stresses, interest in indoor air quality in office buildings is likely to increase. Unfortunately, environmental data on indoor air contaminant exposures in Ontario, representative of occupants in various types of office buildings, are not available, but airborne concentrations of the indoor contaminants are not likely to approach or exceed their respective ACGIH TLVs.

Currently followed energy conservation measures have a direct bearing on the quality of indoor air, and there is considerable disagreement between the hygienist and the building engineer regarding the amount of fresh air required for the health and comfort of the occupants in energy efficient buildings. The subtle health effects of reduced ventilation rates in the energy efficient buildings are not fully known, nor have any significant attempts been made to study them systemically. Comfort concerns are the main complaints.

Résumé

Les facteurs environnementaux affectant la qualité de l'air confiné et les normes d'aération font l'objet de discussions. On peut considérer la qualité de l'air dans les bureaux sous deux aspects : la pollution de l'air et le confort. Le gaz carbonique semble être un élément plus important que le manque d'oxygène en ce qui concerne la quantité d'air frais requise alors que les paramètres du confort comprennent aussi la température, le degré d'humidité et le mouvement de l'air. On en conclut que les problèmes de santé ne constituent pas le principal souci; toutefois, les problèmes d'aération soulèvent des

questions sur le confort et sont la source de la majeure partie des plaintes des occupants.

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An Evaluation of the Vertical Elutriator for Cotton Dust Sampling

Summary

A simple particle sizing technique has been tried to assess the credibility of the elutriator sampling data in a cotton mill. Dust levels measured in the five cotton processing areas of the mill ranged from 0·38 to 0·87 mg/m³. Based on the technique followed and the criteria arbitrarily chosen, the data indicate that the elutriator's size-selective characteristics seemed to conform to its intended design.

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It has been recognized in the literature that byssinosis in cotton mill workers is caused by some 'foreign matter' present in the raw cotton dust and not by the pure cotton fibre itself. It is still not clearly known which components of the dust produce the byssinotic symptoms. The earliest investigators used 'total dust' concentration in cotton mills as an index of dust hazards, assuming a correlation between the total dust measurements and the prevalence of disease. In 1950 Silverman and Viles,[1] in their study of cotton dust levels in air, used a variety of total dust sampling instruments such as impingement type samplers, electrostatic precipitator, thermal precipitator and filters.

In 1960 Roach and Schilling[2] carried out a clinical and environmental study of byssinosis in the Lancashire cotton industry. They used a modified form of Hexhlet to classify cotton dust into the coarse (>2 mm), medium (7μm to 2 mm) and fine (<7 μm) size fractions. They found a good correlation between total dust concentration and byssinosis prevalence. In addition they also analysed the collected dust fractions for cellulose, protein and minerals (ash). The best correlation between dust concentration and byssinosis was found with protein in medium-sized dust (7 μm to 2 mm). The authors further clarified that the study did not prove that byssinosis is caused by the protein in the medium-sized dust and assumed the link, if any, an 'indirect' one.

As opposed to the study by Roach and Schilling,[2] subsequent investigators suggested that fine particles or flyfree dust (medium plus fine fractions) are of more significance in estimating the byssinosis prevalence. In 1961 McKerrow[3] concluded that the fine fraction (<7 μm) of cotton mill dust produces changes in respiratory function and thus it alone may be responsible. In 1970 Roach[4] further proposed his classification of cotton dust exposure based on 'flyfree dust'; i.e., excluding the portion that would be caught on a 2 mm wire mesh.

*The study was completed when the author was employed as a scientist with the Occupational Health Branch, Ontario Ministry of Labour, 400 University Ave., Toronto, Ont.

In the United States a sampler designed by Lynch and Lumsden,[5] known as a vertical elutriator has been extensively used for the environmental monitoring of cotton dust in the cotton mills. In theory this sampler, when operated at a flow rate of 7·4 lpm, is supposed to collect only the particles with an aerodynamic diameter of less than 15 μm. However, several investigators have expressed varying degrees of skepticism about the sampler's 15 μm size cut-off.[6,7,8]

Considering the fact that different cotton handling and processing operations produce different degrees of byssinosis, research is currently underway to relate the prevalence of disease with the particle sizes. Hatcher[9] used a Universal M. Zeiss Optical Microscope interfaced with a particle measurement computer system (millipore Corporation JIMC System). In this automated system dust particles are sized electronically from the TV camera image. In another study Bethea[10] used a specially equipped microscope with a polaroid camera attachment for taking the photographs of the filter surface, without using any clearing liquid to dissolve the filter matrix. Particles were then sized by examination of the photographs.

The vertical elutriator had been in use at the Occupational Health Branch since 1973. From time to time serious doubts had been expressed by the hygiene staff on the performance and usefulness of the elutriator for cotton dust measurements. The general thinking was that the elutriator does not collect the lint-free cotton dust samples. The purpose of this study was to develop a simple method to determine the particle size distribution, which could be used for the estimation of particles greater than 15 μm diameter and lint fibres on the sample filters deposited as a result of penetration through the elutriator's size selective region. Recognizing both the unavailability at the branch of the sophisticated particle sizing equipment mentioned above and the immediate need for evaluating the usefulness of the elutriated cotton dust samples, an attempt, using the available equipment, was made in the summer of 1980 to develop a method to determine the particle size and the lint content of the dust.

Experimental Procedure

As an integral part of a study of the effects of cotton dust exposure in Ontario Textile Mills[11] vertical elutriators were used to collect dust samples in a cotton processing mill. The mill had complete cotton processing

facilities, such as, opening, picking, carding, drawing, roving, spinning and weaving. After a walk-through survey of the plant, sampling sites were selected for the collection of cotton dust samples in four areas: opening, carding, roving and weaving.

Sampling Procedure

The sampling equipment used for this study was the vertical elutriator designed to sample cotton dust at a flow rate of 7·4 lpm. The flow rate was checked against a calibrated rotameter in the field. Samples of elutriated cotton dust were collected on tared cellulose ester membrane filters (millipore AA). Sampling times varied from 150 to 188 minutes. Throughout the sampling interval the flow rate was controlled at $7{\cdot}4 \pm 0{\cdot}2$ lpm and the vacuum was maintained around 14" of mercury.

After sampling, the exposed filters were weighed on a Cahn-21 Automatic electrobalance. Before weighing, the static charge on the filters was removed by passing the filters over a Polonium Source.

Preparation of Filter for Particle Sizing

The method adopted for filter preparation was similar to that recommended by the NIOSH[12] for mounting a filter for asbestos fibre counting. A drop of the clearing solution (mixture of 1:1 diethyl oxalate and dimethylphthalate) was used to dissolve a segment of filter on a microscope slide. A glass cover slip was placed over the filter segment. The filter matrix was allowed about four hours to clear.

Effect of the Mounting Solution on the Cotton Dust and Lint

In order to investigate the solvent effect of the mounting solution on the cotton dust and pure cotton fibres, two slides were prepared:

In one, a drop of mounting solution was added to a fine layer of card room dust, and particles on the slide were examined under the microscope. It was noticed that the particles under observation did not change their shapes or dissolve even after two days.

The second slide was prepared by adding a drop of the mounting solution to pure cotton fibres. When viewed under the phase contrast microscope (400 X

magnification), the aspect ratio of the fibres remained unchanged even after two days. This test, therefore, demonstrated that the phthalate-diethyl oxalate mounting solution dissolves only the filter matrix and not the other particulates. However, this test may not be able to detect the instant solubility, if any, of the dust particles before placing the cover slip for subsequent microscopical examination.

Counting and Particle-Size Measurements

Before commencing particle sizing to determine the lint content of the elutriated dust, it was felt necessary to lay down some ground rules for counting and defining the lint. What is this lint? At what aspect ratio would a cotton fibre be called lint? In the published literature, very little has been mentioned about the quantification of lint on the elutriated cotton dust sample filters. In one reference[10] an aspect ratio of 20:1 to more than 1000:1 has been suggested for the lint fibres.

In order to address the problems associated with the characterization of lint and to meet the objective of this study, lint fibre has been arbitrarily defined as any particle greater than 40 μm in length with aspect ratio 20:1 or greater. From the counting viewpoint, the prepared slides were over-populated with particles. It was, in fact, impossible to count all the particles by following the NIOSH counting rules.

Dust particles on the prepared slides were counted and sized at 400 X magnification using a phase contrast microscope that had a calibrated Patterson Globe and Circle reticle in one of the eye pieces. Initial scanning of the slides showed that they were overloaded with particles. Therefore, instead of following the NIOSH counting rules (100 fibres or 100 fields and a minimum of 20 fields), only 10 randomly selected fields were counted for total particle enumeration. However, for counting particles greater than 15 μm diameter and lint fibres ($>$40 μm length with aspect ratio $\geq$20:1), 50 fields were counted by taking counting traverses across the filter wedge.

For the purpose of this study, the density of cotton dust was assumed to be as one, and the particles were then sized according to their geometric diameter. When density is one, aerodynamic size becomes equal to the geometric size. In this study no attempt was made to determine the density of cotton dust because pure representative cotton dust was not available. However,

the assumption of unit density is supported from the work by Bethea,[10] who estimated the cotton dust density to be equal to 1·27 g/cm^3.

Results and Discussions

Elutriated Cotton Dust Levels

Results of the airborne dust level determinations in each of the five cotton processing areas of the mill are presented in Table 1.

Table 1 **Dust Levels in Cotton Processing Areas**

Location	Dust Concentration (mg/m^3)
Opening	0·55
Picking	0·87
Carding	0·52
Roving	0·38
Weaving	0·63

The data presented in Table 1 shows that, as expected, the dust concentrations are variable for each operation. Dust concentrations range from 0·38 mg/m^3 in roving to a high of 0·87 mg/m^3 in picking. It is also noted that weaving is the next most dusty operation after picking. This observation concerning the presence of high dust levels in the weaving area supports the work by Merchant.[13]

Particle Size Distribution

In the strict sense of the term, the size distribution data presented in Table 2 do not represent a complete breakdown of the distribution of particles in all size ranges. The manual method of microscopic particle counting and sizing proved to be a very laborious, time consuming and eye straining procedure. The particle size distribution, as considered adequate to meet the objective of this study, is presented in Table 2.

Table 2 **Particle Size Distribution Study of the Elutriated Cotton Dust Samples**

Sampling Location	Cotton Dust Mass Conc. (mg/m^3)	Total Number of Particles ($\#/m^3$)	Lint Concentrations (particles >40 μm long aspect ratio 20:1)		Concentration of particles >15 μm diameter (any length)	
			Total Number	Percentage	Total Number	Percentage
			($\#/m^3$)		($\#/m^3$)	
Opening	0·55	17,725,704	75,474	0·42	8,626	0·05
Picking	0·87	26,599,099	123,874	0·47	13,512	0·05
Carding	0·52	14,051,764	91,617	0·65	9,162	0·06
Roving	0·38	16,378,379	67,568	0·41	5,404	0·03
Weaving	0·63	Too dense to count				

The results in Table 2 indicate that the maximum number of particles per cubic metre of air are produced in the weaving area. The morphology of the particles in the weaving room dust was quite different than that observed in other area dust slides. The high dust levels in the weaving area could be attributed to several sources of dust, such as cotton dust remaining after the spinning, fine lint resulting from the shredding of yarn by the weaving machines, indigo dye from the dyed yarn undergoing weaving, starch and other sizing chemicals used in the dyeing department and oil mist resulting from the continuous operation of the weaving machines, etc. The dust collected on the elutriator filter was dark blue in colour, indicating that indigo constituted one of the components of the elutriated dust. On the whole, the dust in the weaving area appeared to be of different composition than the cotton dust sampled in other areas of the mill. This, again, supports Merchant's findings.[13] It would appear from the data in Table 2 that carding produced the highest, and roving the lowest, percentage of coarse particles having greater than 15 μm diameter. However, for all practical purposes this difference may not be significant, and the percentage of such coarse particles (i.e. >15 μm dia.) could reasonably be estimated as less than 0·1 per cent of the total number. This study therefore supports the basic size-selective characteristics of the vertical elutriator: that when operated at the recommended operating conditions the

sampler will collect particles less than 15 μm in diameter.

A review of the published literature revealed that development work pertaining to the quantification of lint fibre number concentrations on the elutriated cotton dust samples has not been reported. This study was therefore also aimed at the quantification of lint on the cotton dust filters. In the absence of any accepted definition of lint fibre, the 40 μm upper cut-off for the length of a fibre was arbitrarily chosen, primarily, to make the particle counting task easier and less eye straining and to improve the precision of the count method.

Conclusion

The unique particle size distribution technique used in this study supports the principle of the vertical elutriator method of sampling cotton dust. The microscopic examination of the elutriated cotton dust indicates that the proportion of particles greater than 15 μm in diameter in the dust samples collected is almost negligible.

Similarly, the percentage of the lint fibres ($>$40 μm in length with aspect ration $\geqslant$20:1) by number on the cotton dust samples is insignificant.

Acknowledgements

I gratefully acknowledge the help and guidance of Dr. D. Leong and Dr. L. Holness in the preparation of this paper.

Résumé

On a essayé une simple technique de mesure des particules pour évaluer si les données obtenues par un séparateur dans une filature de coton sont valables. La proportion de poussière trouvée dans les cinq aires de traitement du coton de l'entreprise allait de 0,38 à 0,87 mg/m^3. Selon la technique utilisée et les critères arbitrairement choisis, les données indiquent que les caractéristiques de sélection des grosseurs du séparateur semblent être conformes au but envisagé.

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Hearing Protection

Summary

Criteria for the evaluation of hearing protection, including regulations, performance standards, selection, use and maintenance are reviewed.

There are three basic approaches to the control of noise and the protection of a worker's hearing. These are: (1) the reduction of noise at the source, (2) the control of noise in transmission, and (3) the reduction of noise at the ear. While the first two approaches represent the most effective ways of eliminating noise hazard in the workplace, the level of technology and expense associated with their implementation often make them impractical.

Under such circumstances, personal protective measures must be taken. Personal protective measures against steady-state and impulsive noise usually depend on the recommended regulatory noise level or exposure standard. In general, to prevent permanent noise-induced hearing loss among workers, hearing protection should be worn where the noise level or exposure is above 85 dBA.

Regulation of Hearing Protectors

In section 144 of the Regulations for Industrial Establishments under the *Occupational Health and Safety Act,* the following references are made to hearing protection.

1. Where a worker is exposed to a sound level of 90 dB or greater, measures should be taken to reduce the sound level below 90 dB, and where such measures are not practicable, the person shall wear hearing protection.
2. Where a worker is exposed to a sound level of 115 dB or greater, he shall wear hearing protection, and
3. Where hearing protection is required, it shall be sufficient to reduce the sound level below that for the corresponding exposure, e.g. 90 dBA for eight hours.

The present regulation approaches the control of a worker's noise exposure, firstly, through engineering controls and, secondly, through the provision and use of hearing protection. It is anticipated that this approach will also continue under the proposed noise regulation.

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Standards for Hearing Protectors

The recognized standard for hearing protectors is the Canadian Standards Association (CSA) Z94.2-1974, (R-1980). This Standard is primarily directed toward the manufacturers of hearing protectors and sets minimal performance requirements for the physical testing of these devices. It includes specifications for required information provided by the manufacturer to the user:

a) Mean sound attenuation in dB at 125-8,000 Hz.
b) Standard deviation in dB at each of the above frequencies.
c) Class of hearing protector.
d) Temperature range and overall weight.
e) Instructions for cleaning.
f) Instructions for use.
g) The test laboratory in which attenuation characteristics are to be determined.

The CSA classification of hearing protectors is based on the mean sound attenuation characteristics, calculated according to the procedure specified in the American National Standards Institute (ANSI) S 3.19-1974. In this procedure, the open ear threshold of audibility is measured and compared with the occluded threshold of audibility (i.e. hearing protectors are worn) by presenting third octave bands of noise with centre frequencies at 125, 250, 500, 1,000, 2,000, 3,150, 4,000, 6,300 and 8,000 Hz. through loudspeakers to normal listeners, (i.e. those whose hearing levels are less than, or equal to, 10 dB between 250-1,000 Hz, and less than, or equal to, 20 dB at all other frequencies).

Table 1 provides the attenuation data in dB at the octave band frequencies between 125 and 8,000 Hz, which must be met for CSA Classification as either 'A', 'B' or 'C' hearing protectors. A Class 'A' hearing protector represents the highest attenuation characteristics achieved under laboratory test conditions.

Table 1 **CSA Standard Z 94.2-1974 (R-1980)**
Hearing Protection
Sound Attenuation Requirements

Frequency in Hertz	Minimum Single Frequency Attenuation in dB	Minimum Single Frequency Attenuation in dB	Minimum Single Frequency Attenuation in dB
125	None	None	None
250	None	None	None
500	29	None	None
1000	35	25	15
2000	35	25	15
3000	35	25	15
4000	35	25	15
6000	None	None	None
8000	None	None	None

At the present time, although these measurements are required by the CSA Standard, there is no Canadian laboratory facility to carry out such testing. In order to comply with CSA requirements, all hearing protectors are currently tested in one of three recognized laboratories in the United States.

The application of the CSA classifications to the noise environment is discussed under 'Selection of Hearing Protectors'.

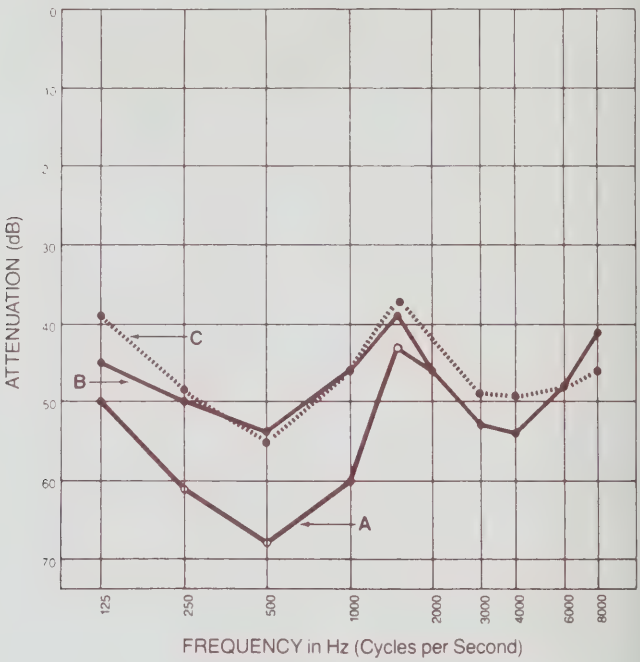
Physical Limitations of Hearing Protectors

Sound stimulates the inner ear either by air conduction or by bone conduction. Air conducted sound is transmitted via the outer and middle ears, while bone conducted sound is transmitted directly to the inner ear, via the skull or bones of the middle ear. In both cases the final sense organ, i.e. the cochlea, is the same, only the path of excitation is different.

For most normal listeners, the bone conduction pathway is much poorer, i.e. less sensitive than the air conduction pathway. There is approximately 50 to 60 dB difference in sensitivity between air conducted sound and bone conducted sound and this difference is illustrated in curve A of Figure 1.

Figure 1

Bone Conduction to Air Conduction Ratio in dB and the Attenuation of Optimal and Real-World Hearing Protectors



Three Attenuation Curves. (A) Attentuation imposed by bone conduction (B) Attenuation of optimal hearing protectors (C) Attenuation of real-world hearing protectors.

Since hearing protectors can only reduce air conducted sound, no hearing protector has the capacity to totally reduce or eliminate sound. A hearing protector should, in theory, be capable of attenuating sound by the amount illustrated in curve A, but because of the occlusion effect, i.e. the increased sensitivity for bone conducted sound with the ears covered, attenuation with hearing protection is limited to the amount shown in curve B.

When the performance of 'real-world' hearing protectors is measured, however, the amount of attenuation is considerably less, as illustrated in curve C. This difference reflects the way in which hearing protectors are fitted under laboratory conditions versus under working conditions.

Based on this laboratory data, one should be highly suspicious of hearing protectors that claim to attenuate sound by more than 40 dB at 250 Hz and 500 Hz, 50 dB at 1,000 Hz, 43 dB at 2,000 Hz, 48 dB at 4,000 Hz and 40 dB at 8,000 Hz.

Selection of Hearing Protectors

In the selection of a hearing protector one must consider three factors: attenuation, application and comfort.

A. Attenuation

To determine the appropriateness of a hearing protector for a worker, consideration must be given to the manufacturer's reported attenuation data and the noise exposure data.

Most noise exposure data have been correlated with the reduction in speech discrimination for individuals trying to communicate in a background of noise. This background noise is measured on the A-weighted network. The attenuation data, however, have been correlated with differences in sound pressure levels using hearing protection, without reference to the A-weighted network. Therefore, a method is required that relates the manufacturer's attenuation data to the worker's specific noise exposure.

There are several methods for doing this; two of them are summarized below.

The first method utilizes the CSA classification system and applies it to the background noise level measured on the A-weighted network.

Steady State Noise	CSA Classification
80-89 dBA	C
90-105 dBA	B
over 105 dBA	A
Impulse Noise	
over 115 dB (peak pressure)	A

Hearing protectors selected on this basis should attenuate background noise to a target sound level of 85 dBA.

Unfortunately, most manufacturers do not classify their products with the A, B or C rating. Instead, they provide the mean attenuations and standard deviations at each of the octave bands between 125 and 8,000 Hz and leave it to the user to compare the attenuation data with those of the CSA Standard in order to derive the classification of the hearing protector.

For example, the following mean attenuations and Standard deviations were achieved on ear muffs tested under laboratory conditions.

Frequency Hz	125	250	500	1,000	2,000	3,000	4,000	5,000	8,000
Mean value	23	25	31	36	40	42	42	39	37
1 Std. deviation	2.2	2.0	1.9	2.2	2.0	2.3	3.2	3.2	3.0

When these values are compared to the mean attenuation criteria for CSA classification (see Table 1), it can be seen that the ear muffs are a Class A rated device.

The selection of these ear muffs where noise levels reach 105 dBA or more would be considered appropriate since a target sound level of at least 85 dBA could be achieved.

105 dBA—35=70 dBA

The second method utilizes the Noise Reduction Rating (NRR) developed by NIOSH in 1975 and adopted by the EPA in 1977. This single number decriptor represents the overall attenuation for a hearing protector that can be applied directly to the background noise level measured on the C-weighted network.

For example, the NRR for the ear muffs referred to in the above example is 29. The selection of these ear muffs where noise levels reach 105 dBC would be considered appropriate since a target sound level of at least 85 dBA could be achieved.

105 dBC—29 (NRR)=76 dBA

Because most manufacturers routinely include the NRR, either on the product itself or in the product literature, its direct application is considerably easier and more convenient than CSA classification.

It must be stressed that neither the NRR nor the CSA

classifications should be used in isolation. Both must be applied to the background noise levels.

In most cases this approach will eliminate arguments over the absolute value of the hearing protector. For example, a hearing protector with an NRR of 26 dB may be just as appropriate as one with an NRR of 20 dB, and, likewise, a hearing protector with a CSA classification of B may be just as appropriate as one with a classification of A. The critical factor is whether or not the target sound level of 85 dBA can be achieved with the hearing protector. If it can, then the hearing protector qualifies for selection regardless of the greater potential for attenuation of another hearing protective device.

B. Application

In the selection of a hearing protector consideration must also be given to the suitability of a particular device for use by a worker in a specific work area. This is addressed by reviewing the advantages and disadvantages of earplugs and ear muffs, some of which have been summarized below:

Ear Muffs: Advantages

1. Generally offer maximal attenuation in the higher frequencies.
2. More dependable and stable performance over a longer period of time.
3. Minimal fitting problems.
4. Generally more acceptable to employees in the early stages of a hearing conservation program.
5. Can be used with minor ear infections.
6. Not easily lost, forgotten or misplaced.
7. Relatively easy to monitor their use from a distance.
8. Have a longer wearing life.
9. Serve dual purpose: protect ears from sparks as well as noise.

Ear Muffs: Disadvantages

1. Uncomfortable in warm environment.
2. Uncomfortable because of pressure against the head, which may cause headaches.
3. Cumbersome to carry and store.
4. Relatively troublesome when wearing safety glasses, hardhats, face shields and other head gear.
5. Cumbersome in confined areas.

Earplugs: Advantages

1. Generally offer maximal attenuation in low to mid frequencies.
2. Relatively more comfortable in warm environment.
3. Easy to carry and store.
4. Relatively convenient and allow freedom of head movement.
5. Create no particular problem with safety glasses and/or other personal protective equipment.

Earplugs: Disadvantages

1. Easy to lose, forget or misplace.
2. Should not be used with ear infections.
3. May irritate the ear canal.
4. Provide less stable attenuation because of jaw movement.
5. Become dirty and require regular washing.
6. More difficult to monitor their use from a distance.

C. Comfort

The comfort of a hearing protector will ultimately affect whether it is accepted and worn by the worker. Therefore, comfort must also be given consideration in the selection of a hearing protector.

The best approach to dealing with the issue of comfort is to advise the worker that hearing protection, just like any other personal protective equipment, has not been designed primarily for comfort. Therefore *all* hearing protection will initially cause some minor discomfort and will require a period of adjustment before it can be tolerated by a worker for the entire work shift.

Once the worker realizes the benefits derived from the regular use of hearing protection, e.g., no temporary or permanent hearing loss and improved communication ability, the objections and the resistance should disappear.

Use of Hearing Protectors

Even when workers regularly use hearing protectors, increased hearing loss may be observed for the following reasons:

1. Hearing protectors may not be worn during the entire noise exposure period.
2. Hearing protectors may not fit properly.
3. Workers may not have been instructed in the proper fit, care and use of hearing protectors.

4. Workers may alter hearing protectors to make them more comfortable.

To ensure good compliance in the provision and use of hearing protection, the CSA Committee on Hearing Protection has recommended the following:

Draft Appendix A2. CSA Standard Z94.2 - 1974. Fit, Care and Use of Hearing Protection

1. Workers should be informed of the company policy regarding the purpose of the Hearing Conservation Program and the use of hearing protection to control noise exposure.
2. Before fitting hearing protectors, a visual inspection of the external ear should be carried out to identify ear problems, e.g., impacted wax, infections or discharge, which may interfere with, or be aggravated by, the use of hearing protectors. If any of these conditions are identified, the worker should be referred for medical investigation. When premolded or custom molded ear plugs are selected, the ear canals should be individually appraised for correct size and shape of hearing protector.
3. The selection and fitting of hearing protectors should involve the worker. He/she should be given a choice from among several types of appropriate hearing protectors, e.g., at least two ear plugs and one ear muff. A trial period should be provided with each of these, if necessary.
4. Hearing protectors should be fitted in accordance with the manufacturer's instructions when available, and these reviewed with the worker. Hearing protectors are properly fitted when there are no leaks through or around the hearing protector, i.e., when there is an effective seal between the ear plug and the ear canal or between the ear muff and the head.
5. The proper fitting technique for ear plugs and ear muffs should be demonstrated, and the technique practised by the worker under close supervision.

For proper fitting of ear plugs, the ear should be pulled up and back with the opposite hand to enlarge and straighten the ear canal. The ear plugs should be inserted with clean hands. For proper fitting of ear muffs, hair and clothing should be pushed back away from the ear and the ear muff cushions placed directly over and around the ears. The headband must be adjusted according to the manufacturer's instructions, when available.

6. When ear muffs are used in ways other than those prescribed in the original design, e.g., over glasses or long hair, the worker should be made aware that the amount of attenuation provided by the hearing protector could be reduced.
7. Hearing protectors should be maintained in the best operative condition. Any alteration in ear muffs or ear plugs by the worker (e.g., drilling holes in the earcups, trimming or removing flanges on premolded plugs) will reduce the amount of attenuation recommended by the manufacturer for that particular hearing protector.
8. The condition and fit of hearing protectors should be examined routinely both in the work area and at the time of annual audiometric test. Defective hearing protectors, poorly fitting hearing protectors and improper fitting techniques should be identified and corrected.

Ear plugs and ear muff cushions should be kept clean and pliable. When an earplug or ear muff is used daily, it should be replaced at least every six months, and ear muff cushions at least every year.
9. A worker who demonstrates significant deterioration in hearing on audiometric tests should receive additional counselling with regard to the proper fit, care and use of hearing protectors for both occupational and recreational noise exposure. In addition, the use of hearing protection in the work area should be monitored.
10. In noisy work areas where the use of communication head-sets is required in combination with hearing protection, the attenuation characteristics must not be compromised. The volume control should be set to a level adequate for effective communication, and the headset or amplifier should have peak limiting capability. The worker should be counselled that setting the volume control to an excessively loud level will damage hearing.
11. Under no circumstances should the use of recreational earphones associated with stereo headsets be allowed as a alternative form of hearing protection.
12. In noisy work areas where the wearing of hearing protection is required, clearly visible warning signs should be posted.

Hearing Protection Audit Protocol: Suggested Criteria for Evaluating the Hearing Protection Component in a Hearing Conservation Program

Do you:

1. select appropriate hearing protectors by:
   a) reviewing the attenuation data, and carrying out noise measurements to determine if the hearing protector will meet a target sound level of 85 dBA?;
   e.g. dBC—NRR=85 dBA.
   e.g. Class A/B/C=85 dBA.
   b) considering the advantages and disadvantages of earplugs or ear muffs for use by a particular worker because of his job, work location, work conditions, use of other personal protective equipment, availability of hygiene facilities and communication needs?;
2. give workers a choice of hearing protectors (at least two earplugs and one ear muff) that meet the attenuation requirements?;
3. inform workers through an educational program of the effects of noise on hearing, the rationale behind the Hearing Conservation Program and the provision of hearing protectors?;
4. demonstrate the proper fitting technique(s) for the hearing protector(s) chosen by the worker?;
5. have the worker practise the proper fitting technique under close supervison?;
6. have a proper maintenance/hygiene program for hearing protectors?;
7. monitor the worker's use of hearing protectors in the work location?;
8. evaluate the condition and fit of hearing protectors at the time of the audiometric test?;
9. review with workers the results of hearing tests to reinforce the importance of regular and proper use of hearing protectors in the prevention of noise induced hearing loss?

Types of Hearing Protectors

1. Inserts

a) Premolded Earplugs

Premolded earplugs are made of soft silicone, rubber or plastic. They are usually available in a range of sizes: small, medium, large, extra small and extra large. These earplugs must be fitted individually since ear size and shape are not always symmetrical.

With continuous use, premolded earplugs may shrink and become hard depending on the temperature of the

workplace and personal hygiene. Regular cleaning with soap and water is required to prolong the useful life of premolded earplugs.

b) Custom Molded Earplugs

Custom molded earplugs are individually constructed. Considerable skill and experience is required for them to be made properly.

Regular cleaning with soap and water is required to prolong the useful life of these earplugs.

c) Formable Earplugs

Formable earplugs are made of foam or plastic-like material. The insertion of formable earplugs requires that they be compressed or formed, usually by rolling them between the thumb and index finger. After insertion into the ear canal the foam plug assumes its original shape expanding against the ear canal to form a seal.

When using foam earplugs the worker must be instructed in the proper insertion technique and the importance of personal hygiene. These earplugs are designed for single use, but with proper hygiene, can be re-used.

d) Amplitude Sensitive Earplugs

Amplitude sensitive, non-linear or active earplugs are designed to provide attenuation that increases with the sound level. These earplugs have a small orifice running longitudinally through the body of the plug, which contains a valve or acoustical damping material.

At sound levels less than 110 dB these earplugs provide almost no attenuation below 1,000 Hz, while at frequencies above 1,000 Hz they provide about 30 dB of attenuation. At sound levels greater than 130 dB, turbulent air flow is generated in the orifice of the earplug, which impedes the transmission of sound.

Amplitude sensitive earplugs are of little value for most occupational or recreational noise exposure where noise is steady-state and less than the level (110 dB) required for them to become functional.

At the present time, amplitude sensitive earplugs are not tested according to the procedures specified in the CSA Standard.

General Advice for Workers on the use of Earplugs

1. Make the ear canal accessible by reaching over the head with the opposite hand and pulling the ear up and back.
2. When earplugs are properly seated the voice should sound muffled and lower.
3. Even a small leak will reduce the protection provided by earplugs.
4. Because earplugs tend to work loose as a result of talking or chewing, they sould be reseated.
5. Earplugs should be kept clean with soap and water, and when not in use should be kept in the carrying case.

2. Semi-Inserts

Semi-inserts are premolded earplugs made of soft silicone rubber or plastic, and suspended on a headband. They are inserted into the ear canal and form a seal against the external edges of the concha.

Regular cleaning with soap and water is required to prolong the useful life of these earplugs.

General Advice for Workers on the Use of Semi-Inserts

1. Turn the headband to the desired postion, then adjust caps so that the arrow is on top pointing forward when set in the ear.
2. Grasp each cap with thumb and index finger and work them into the ear until the ear canal is completely sealed.
3. When semi-inserts are properly seated, the voice should sound muffled and lower.
4. Even a small leak will reduce the protection provided by semi-inserts.
5. Semi-inserts should be kept clean with soap and water.

3. Ear Muffs

Ear muffs consist of two dome-shaped earcups lined with acoustically absorbent material that fit over the external ear and form a seal against the side of the head. The ear muffs are held in place by a spring loaded suspension assembly, which is designed to be worn in one of three positions—over the head, behind the head and under the chin.

Ear muffs are also attached to hardhats, convenient for use when noise exposure is intermittent. The ear muffs can be placed on top of the hardhat when not required.

Ear muffs are supplied with replaceable ear cushions that are either liquid or foam filled. The outer covering of the ear cushion is made of vinyl, and with regular use will become hard and cracked. Ear cushions must be cleaned and replaced periodically.

General Advice for Workers on the Use of Ear Muffs

1. Adjust the headband to ensure that the ear cushions are in complete contact with the head.
2. When ear muffs are properly seated, the voice should sound muffled and lower.
3. Even a small leak will reduce the protection provided by ear muffs.
4. The headband, earcups, ear cushions or liners should not be altered or bent.
5. Ear cushions should be kept clean, and replaced if they become hardened or cracked.

Résumé

Les critères d'évaluation de la protection de l'ouie, y compris les réglements, les normes de rendement, la sélection, l'utilisation et l'entretien, font l'objet d'un examen.

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Book Review

Canadian Occupational Health and Safety Law Handbook.

Michael Izumi Nash.
A project of the Canadian Environmental Law Research Foundation.

Published by CCH Canadian Limited, 6 Garmond Court, Don Mills, Ontario M3C 1Z5

Price $15.00 from the publisher.

Occupational health professionals reading this book should read the introduction last. Otherwise they may be turned away from a well done and useful piece of work.

As the title implies, the author has attempted to interpret the intricacies and often incomprehensible legalese of various Canadian Occupational Health and Safety laws. He has been generally successful, and has clarified the 'intent' of the various laws in a way that would be understandable to most readers. While the reviewer is unable to comment on the legal validity, familiar laws and regulations seem to be well and properly interpreted.

However, this is not the main thrust of the book; it is essentially a step-by-step guidebook designed to enable employees to identify, clarify and assert their legal rights relative to health and safety in the workplace.

The book is divided into five general sections; the first identifies specific occupational health and safety legislation, other relevant laws and appropriate sources for further information. There is a particularly useful appendix listing the coverage by jurisdiction, industry and hazard.

The second section deals with access to information about the workplace, and how and when such information can be obtained. It includes a short chapter dealing with access to medical records.

The third section outlines the function of health and safety committees. Part Four, dealing with the enforcement of health and safety law, includes a good overview of the right to refuse work.

The last section deals with workers' compensation and appeal procedures.

Finally, the Introduction. The author's personal bias is clear from the Introduction; nonetheless, he generally has succeeded in dealing very evenly with the subject throughout the book. Wherever 'rights' are discussed, so are the corresponding 'responsibilities' of the employee as well as those of the employer.

This book will be of use both to physicians and managers. Particular attention should be paid to the

model collective bargaining clauses included in the Appendix.

It will be particularly valuable to part-time occupational health physicians who have little time to sort out the finer intricacies of occupational health and safety law and workers' compensation legislation and how they relate to physicians' responsibilities to employees.

E.S. Gibson

Publications Available from the Government Book Store

Publications under the Regulation Act vol. 112-39	
Revised Regulations of Ontario, 1980 Regulation 692/80 Industrial Establishments	$2.00
Revised Regulations of Ontario, 1980 Regulation 691/80 Construction Projects	$2.00
Revised Regulations of Ontario, 1980 Regulation 694/80 Mines and Mining Plants	$2.00
Regulation respecting Lead— made under the Occupational Health and Safety Act Ontario Regulation 536/81	$1.00
Regulation respecting Mercury— made under the Occupational Health and Safety Act Ontario Regulation 141/82	$1.00
Regulation respecting Vinyl Chloride— made under the Occupational Health and Safety Act Ontario Regulation 516/82	$1.00
Regulation respecting Coke Oven Emissions— made under the Occupational Health and Safety Act Ontario Regulation 517/82	$1.00
Regulation respecting Asbestos— made under the Occupational Health and Safety Act Ontario Regulation 570/82	$1.00
An Occupational Health Nurse's Guide to the Preparation of a Policy and Procedure Manual	$2.00
A Guide to The Occupational Health and Safety Act, 1978	$1.00

News and Notes

Occupational Health Clinic Awarded $147,032.00

Russell H. Ramsay, Minister of Labour, has approved a $147,032.00 grant for the Occupational Health Clinic at St. Michael's Hospital.

The clinic, under the leadership of Dr. James R. Nethercott, Director of the Occupational and Environmental Health Unit, University of Toronto, was initiated in February 1981 to serve the growing demand for attention to occupational health. The clinic specializes in the investigation, diagnosis and treatment of occupational illness and is the first hospital-based clinic of its kind in Canada.

In addition to regular medical patient treatment facilities, the clinic offers a variety of special services to government, labour and private industry. These services include complete workplace evaluation consulting, medical and epidemiological research, a full teaching program and a computerized information service focused on occupational health problems and topical concerns.

The clinic is dedicated to the prevention of occupational illness, the promotion of good health practices and comprehensive treatment of existing problems. The Ministry of Labour grant will make it possible for the clinic to continue to strive towards these goals.

Fifth Five-day Intensive Workshop in Industrial Hygiene

The Fifth Five-day Intensive Workshop in Industrial Hygiene, organized by the Department of Chemical Engineering and Applied Chemistry, University of Toronto, will be held Monday, September 27th through Saturday, October 1st, 1983. The panel of lecturers includes Dr. John Steel, Dip.Occ.Hyg., of Newcastle-upon-Tyne, United Kingdom, and staff in the University of Toronto. Professor J.F. Richardson of the University of Swansea, United Kingdom, will deliver a banquet address on 'Hazard Identification Control'.

The expertise of the 14 speakers covers all the relevant aspects of hygiene, human factors engineering, toxicology and occupational medicine. A hands-on equipment demonstration is included in the workshop.

The problem of coping with Ontario's Designated Substances will be specifically addressed.

The workshop is part of the Industrial Hygiene and Hazard Control Engineering Program of the University of Toronto in association with the Canadian Society for Chemical Engineering, the Occupational and Environmental Health Unit, Faculty of Medicine, University of Toronto and the Industrial Accident Prevention Association of Ontario. Enquiries should be addressed to:

Professor J.W. Smith, C.I.H.,
Department of Chemical Engineering and Applied Chemistry,
University of Toronto,
Toronto, Ontario, M5S 1A4

Coming Events

August 28- September 2, 1983	American Chemical Society Symposium on Chlorinated Diseases and Dibenzofurans in the Total Environment, II.
September 10-14, 1983	9th International Congress on Agricultural Medicine, Christchurch, New Zealand. Details from John Stoke, Deputy Director (Occupational Health), Division of Public Health, Department of Health, Macarthy Trust Building, Lambton Quay, Wellington, New Zealand.
September 13-17, 1983	VI International Symposium on Occupational Health in the Production of Artificial Organic Fibres, Permanent Commission and International Association on Occupational Health, Mannheim, Federal Republic of Germany.
September 20-23, 1983	VIth International Pneumoconiosis Conference, Ministry of Labour and Social Affairs of the Federal Republic of Germany, Bochum, Federal Republic of Germany.
September 26-29, 1983	XIth International Congress on Occupational Health in the Chemical Industry, Calgary, Alberta.
September 28-30, 1983	3rd Conference on Epidemiology in Occupational Health, Singapore.
October 2-5, 1983	Annual Scientific Meeting, College of Family Physicians of Canada, Toronto, Ontario.
October 18-20, 1983	Three-day International Conference on Offshore Safety and Health (ICOSH), Halifax, Nova Scotia.
October 24-28, 1983	Annual Conference, Ontario Occupational Health Nurses' Association, Waterloo, Ontario.
December 12-15, 1983	International Seminar on Methods of Monitoring Human Exposure to Carcinogenic and Mutagenic Agents, Espoo, Finland.
September 5-10, 1984	XXI International Congress on Occupational Health, Dublin, Ireland.

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ISSN 0705-9388